

Mechanics, Logistics and Economics of Transporting Easter Island (Rapa Nui) Statues

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Introduction

This paper presents an analytical approach to megalithic statue (*moai*) transport on Easter Island (Rapa Nui). Archaeological field inventory has yielded metric data describing 55 morphological attributes of 887 *moai*. Of this number, 383 *moai* were sufficiently intact to be entered in a computerized data base (Cristino et al. 1981; Van Tilburg 1986; Vargas 1988; Gonzalez et al. 1988). An isolated subset of 134 *moai*, each possessing ten crucial measurements defining individual size, shape, weight and proportionate relationships of head to body, was submitted to cluster analysis. Six groupings of morphologically similar statues resulted, four of which are viable (Van Tilburg 1993: 91-2). Further analysis determined that the morphologically and statistically average statue transported from Rano Raraku quarry to various extra-quarry locations was a vertically rectangular cylinder standing 4.05 m tall and weighing 12.5 m tons (Van Tilburg 1993: 94, Figure 3). A transport model hypothesized for this average *moai* thus may be generalized with confidence to 46.9% of the *moai* in the study.

Previous Research and Speculation

The physical evidence of ancient heavy transport in a wide variety of prehistoric megalithic cultures has been variously investigated, and numerous attempts at reconstructing methods using ethnographic data described (cf. Heizer 1966; McKern 1929; Ferdon 1987; Thorp and Williams 1991; Van Tilburg 1994:148, 173, note 1 for overview). For Easter Island specifically, overland transport methods have been proposed in which the statue or statue replica used was discrete, therefore not allowing extrapolation to other *moai* with validity. The primary *moai* variables in each are gross size and position. In the first method, a real 4 m. tall *moai* assumed a horizontal, supine position on a wooden sledge of not fully specified design (Heyerdahl and Ferdon 1961: Plate 60b; Pavel 1990:142, Figure 1 suggests a variation). It was then hauled a few meters over flat ground by somewhere between 75 and 180 people (Skjølsvold 1961:370-71; Ferdon pers. comm. 1993).

Katherine Routledge (1919:194-99) examined statues strewn along roads she mapped between Rano Raraku and other parts of the island. Because of the patterns of breakage she observed on some, she first suggested and then abandoned the idea that they were transported upright. Instead, she presumed that at least some were standing upright in place to form a "ceremonial road," a point of view increasingly supported by emerging evidence. Subsequently, her original idea, coupled with the unwarranted literal interpretation of a single, metaphorical, late Rapa Nui tradition (that the statues "walked" through the power [*mana*] of chiefs and priests) inspired three versions of more or less upright transport methods. Mulloy (1970) suggested an overly complicated, resource intensive and largely unworkable bipod for moving Paro, the largest statue successfully erected on *ahu*,

in a prone position (Cotterell and Kamminga 1990 for critique). Pavel (1990:141-4) used ropes to pull, incline and turn a statue replica on its base in an upright position. This method was subsequently attempted on a real statue, which was damaged in the process (Heyerdahl 1989). Love (1990:139-40) varied the same upright method by attaching a "pod" of short logs to the base of a replica statue and then moving it a short distance over flat ground with the use of rollers (Van Tilburg 1994, 1995 for critique).

The possibility of statue transport by water has been occasionally mentioned, and was suggested at Vinapu on the basis of the physical qualities of a small, sheltering bay and scant archaeological evidence (Mulloy 1961:93). Remnants of stone "canoe ramps" associated with *ahu* are evident at Hanga Te Tenga on the southeast coast and elsewhere. At the conjoined sites of Ahu Tahai, Ahu Ko Te Riku and Ahu Vai Uri on the west coast restored ramp and wharf areas exist. The purpose of such ramps, whether practical, ceremonial or both, is completely unknown. Could they have been used to receive statues, first hauled overland from Rano Raraku and then floated by raft along the coast? There are many variables of archaeology, architecture, statue morphology, natural and human resources, time and political reality to be factored into such a notion, and the necessity of such a high-risk undertaking, assuming it ever happened, is unclear¹.

Research Design

Statue 01/53 at Ahu Akivi (16-100), a restored and dated ceremonial site (*ahu*) lying about 140 m above sea level on the southwestern slope of Maunga Tere Vaka, was one of several which fit our statistically defined average (Mulloy and Figueroa G-H 1978; Ayres n.d.; Van Tilburg 1994, 49, Figure 33). It was chosen as "reference *moai*" because its state of preservation, accessible location and upright position promised control points of a B-patch, allowing a smooth representation of the island's terrain (Shiller and Gwo 1991:241-9; Van Tilburg et al. n.d. [in prep.]). Paths were generated by a good opportunity for thorough metric and photogrammetric documentation, allowing creation of full scale and 1/10 scale model *moai* (Van Tilburg 1992b). Laser scan operations generated a three-dimensional computer image which was used to hypothesize and test simulated transport methods within the parameters of a defined time frame and natural resource availability criteria (Van Tilburg 1993:99, Figure 9.8).

The primary objective of the transport experiments was to compute paths over which the "reference *moai*" could have been moved from Rano Raraku, where it was carved, to the destination site of Ahu Akivi, where it was erected with six others nearly precisely the same, on the second and final construction phase of the *ahu* sometime after cal. AD 1442 and before the mid-1600s (Ayres n.d.). Following Vargas (1993:104), Ahu Akivi is considered to be within the "coastal zone," defined as "bounded by the volcanic platform that

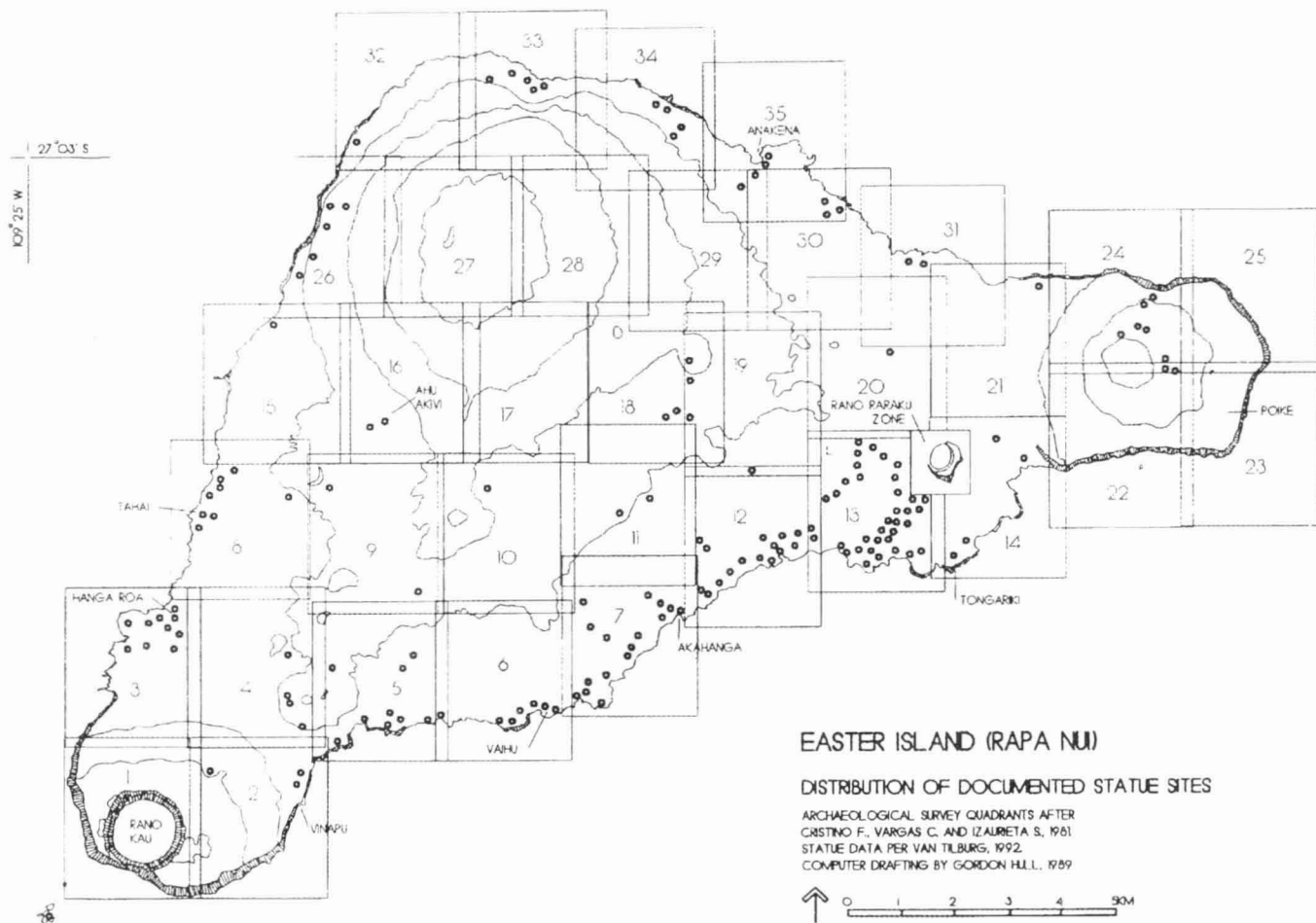


Figure 1. Map of Easter Island showing archaeological survey quadrants, 100 m contour lines and the distribution of statues.

joined together the three main volcanoes on the island, Poike, Tere Vaka and Rano Kau, while the interior zone is 160 m above sea level." The site is within the Ko Tu'u or western confederacy, the higher ranked of the two largest ethnographically recorded Rapa Nui political divisions (Routledge 1919:222). As part of the dominant Miru kin group (*mata*), the chiefly head of the lineage (*ure*) which controlled the hereditary lands on which Ahu Akivi is located was entitled to the designation *ariki*. Ahu Akivi is associated with an extensive community which lay between the *ahu* and Ahu Tepeu on the western shoreline some 2.6 km. distant. Notwithstanding Ahu Akivi's relative distance from the coast, marine food resources, controlled largely by the dominant Miru, would have been available.

The *ahu* platform itself is a relatively simple and straightforward elevated, rectangular structure with a cleared ceremonial space at the front (Mulloy and Figueroa 1978: figs. 1, 2, 15). It lacks the red scoria fascia often present on more elaborated *ahu* structures, and the statues lack red scoria "headdresses" (*pukao*) nearly exclusively present on coastal sites. Statue 01/53 could have approached Ahu Akivi conveniently from either the front or rear of the platform and in either a prone or supine position, and no substantial deterrents to maneuvering the statue on site are archaeologi-

cally apparent. Methods for actually erecting the *moai* have been speculated upon elsewhere (Routledge 1919; Van Tilburg 1994, 1995).

We hypothesized that the energy required to transport the *moai* might have been a major factor influencing transport path selection. Energy requirement, in turn, specified the number of people and amount of time required to move the statue over mapped terrain and allowed calculation of total food consumption during the journey. The result is an estimation of minimum social unit size involvement in the average transport task.

To allow computation of transport paths, a 1:30,000 map of Rapa Nui was tessellated into a uniform grid at increments of 285 m. The elevation of each grid point was recorded and entered into a data base. These points were then used as the smooth B spline that is guaranteed to be on the surface. This representation adequately conveys the general slopes of the island terrain and the distance traveled (Figure 1).

Transport Model Design

There are, theoretically, several ways the *moai* could have been moved (Skjølsvold 1961:370-71; Van Tilburg 1994:152-156). Some of these are more viable than others but all require tests of reason and simplicity for their validity.

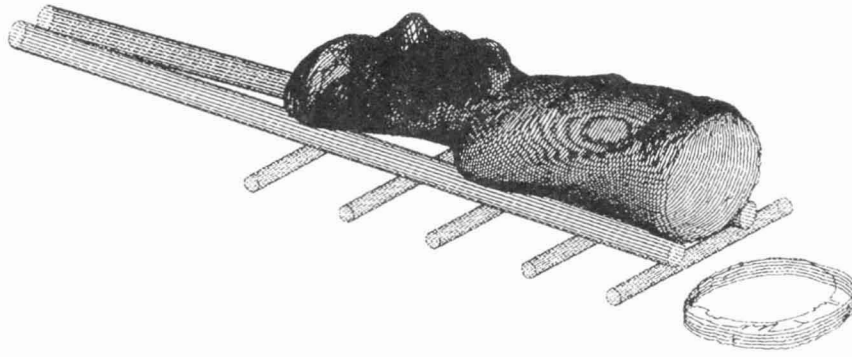


Figure 2. A supine statue moved on large diameter rollers to provide sufficient ground clearance.

Consequently, we rejected the methods previously suggested as unworkable, dangerous and not indicated for either the terrain or the task.² We hypothesized a single, horizontal transport method which allowed two significant variations. Our method is based upon published contemporary observations of megalithic transport in several discrete cultures, experimental archaeology projects of well-documented utility in other locales, Polynesian canoe construction methods, historic Rapa Nui statue transport events and observations, Rapa Nui terrain reality, resource availability, statue attributes and archaeological contexts (Van Tilburg 1994:155, fig. 123; 1995).³

In our computer simulations, we moved the Statue 01/53 "reference *moai*" in a supine position on a simple "sledge" constructed of two nonparallel wood beams 5 m long and 10 cm in diameter. The beams, which add no appreciable weight to the transport task, are held in place by the weight of the statue alone. The non-parallel (V-shaped) nature of beam placement is dictated by the form and weight properties of the statue, and is crucial to the success of the method. The statue on its beams is hauled over a minimum of five rollers at a time, each at least 10 cm in diameter, or a combination of similar rollers and sleepers, by means of attached ropes.

If the statue assumes a prone position, two simple variations are suggested. A prone statue was moved by increasing the diameter of the rollers to at least 25-30 cm, thus raising the entire statue 15 to 20 cm higher off the ground (Figure 2). Alternatively, two crossbars of 25-30 cm diameter were inserted between the statue and the two non-parallel transport beams supporting it. In both prone variations, the goal was to raise the face and nose of the *moai* sufficiently far from the ground to avoid damage (Figure 3). Apparent stresses at the statue's vulnerable neck are present in both positions, but more easily mitigated when it is supine.

The horizontal *moai*, in either a supine or prone position, is presumed to have been hauled head first over rollers by as many people as were required to overcome attendant frictional and gravity forces (Wong 1978). The overland distance from Rano Raraku to Ahu Akivi varies from 10.1 km to 14.45 km., depending upon which of 3 proposed paths was chosen (Van Tilburg 1994:156, Figure 124).

Power Output and Metabolic Performance Model

Gender specific labor division was assumed, and a power output and metabolic performance model was created. From this and the osteological data available for the same time period, a Rapa Nui "reference man" best qualified to perform the required work of hauling was hypothesized (Murrill 1965). This "reference man" was between the ages of 18 and 30 and in generally good health, possibly with mild bone deficiency. A conservative estimate of stature (height: 172.7 cm) and robusticity (weight: 70 kg) was extrapolated (cf. Astrand and Rodahl 1970; Collins and Roberts 1988; Garhammer 1980; Owsley pers. comm. 1993; Gill

pers. comm. 1993 suggests we may be conservative in our estimate). From the estimated average generated power output of 0.3 HP (R. Gregor, pers. comm. 1993) we calculated the steady state speed at which the *moai* could be moved.

Optimal Path 1, which approximates a portion of what Routledge (1919:Figure 74) called the "western image road," is 10.1 km long. The total time investment (not span) required to move Statue 01/53 over Path 1 from Rano Raraku was 4.7 days. The required work force varied between 20 and 70 individuals, depending upon the terrain slope at each grid point. The most difficult point along Path 1 is towards the end, at the 8th km, where the relatively steep slopes required the largest number of people.

Data from Western Polynesia indicate that individual extended families could be expected to have 45 to 50 people and at least 8 males of age and vigor appropriate to our Rapa Nui "reference man" (Lay 1959). This means that 8.7 extended families (between 391 and 435 people) joined forces to work and provide food for the Statue 01/53 transport crew. Cumulative survey data illustrate that cooked food preparation was not accomplished routinely along the transport route. Drinking water, vital to the prevention of muscle fatigue and dehydration, was available both at the quarry and at the destination site, and gourd vessels could have been used to carry it.

In order to adequately support itself under normal conditions, each of these extended families required access to 22 to 25 acres of cultivated land. At an optimum daily diet per worker of 2,880 calories, a collective total of 201,600 calories per day was required. At a calculated yield per acre for each of 2 Rapa Nui agricultural staples (sweet potatoes and bananas), the Rapa Nui *ariki* who commissioned the Path 1 Ahu Akivi transport task would have been required to have political and economic access, above and beyond his normal extended family requirement, to the productive yield of an additional 1.5 to 3.0 acres of cultivated sweet potatoes and between 1.6 and 3.2 acres of bananas. If we consider normal fallow/productive ratios, that number of accessible acres must be doubled to between 3 and 6.

To replace the energy and body tissue being expended in the work task, each worker also required 65-75 g of protein

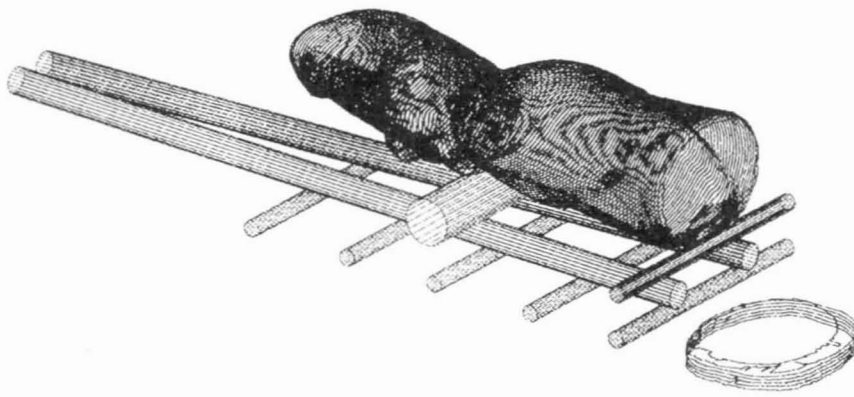


Figure 3. A prone statue moved with cross bars to provide sufficient ground clearance.

and 15 g of iron. Ideally, each worker should thus consume either 200 g of chicken or an equal amount of relatively non-oily fish such as tuna in order to gain 500-600 calories of protein. A stored agricultural surplus at least equal to what was being expended in the work task is postulated to have been required to secure the necessary protein through trade, engage the requisite master carver or carvers who supervised the transport task, meet the daily nutritional needs of extended family not directly involved and "feed the gods" as well.

Sociopolitical Implications

Thus we arrive at the economic and political definition of the average Rapa Nui chiefdom capable of completing the average statue Path 1 transport task within a defined locale, a generalized time frame and a specified length of time. This political unit, which conforms to the "simple chiefdom" model (Earle 1991:3; Green 1993:226-7), consists of between 391 and 435 people. When the transport model is extended to accommodate the two largest statues successfully moved outside the quarry zone (Paro on the northeast coast at 9.8 m and a statue at Hanga Te Tenga on the southeast coast which is 9.9 m tall), food resource investment may be increased by a factor of 6.5 but is also balanced by appreciably decreased travel distances in both cases. The numbers of people involved in each discrete situation increase to between 2,542 and 2,828. One implication of this, of course, is that social integration in these two parts of the island increased proportionately, at least for a certain time.

The Statue 01/53 transport task probably took place from only 100 to less than 300 years before European contact. From the middle portion of this approximate time frame (AD 1500s and continuing well into the 1800s), evolved ideological practices produced the *tangata manu* (birdman) cult at the pan-island site of 'Orongo. Some temporal overlap between *moai* quarrying at Rano Raraku, continued megalithic activity at lineage or combined lineage *ahu* and the development of 'Orongo is obvious. Thus, we should not be surprised when we find, as we clearly do, evidence of behavior conceptually linking *ahu*, *moai*, Rano Raraku and Rano Kau.

For example, the presence of the basalt statue Hoa

Hakanana'ia at the petroglyph-rich site of 'Orongo, with its superimposed dorsal carvings, relates to similarly carved statues on several *ahu* and at Rano Raraku, where many *moai* are retained and erected *in situ*, not on *ahu* (Routledge 1919, Figure 64; Van Tilburg 1992a). Ethnographic descriptions of the physical appearance of birdmen were recorded by Routledge (1919), and are graphically and dramatically made real in Tukuturi, the kneeling statue of Rano Raraku (Van Tilburg 1994:28). The stone houses of 'Orongo, apparently seasonally inhabited by *rongorongo* experts and priests of high status (*Ivi atua*), are echoed in the foundations of *hare paenga* (elliptical houses) which ring the entire outer parameter of Rano Raraku at the 50-75 m contour

level and at an apparently late point in time. My own opinion is that the plethora of petroglyphs at 'Orongo and the *moai* standing erect on the inner and outer slopes of Rano Raraku are conceptually similar, as Routledge originally suggested. Accounts by such reliable Rapa Nui informants as Viriamo Huki a Puhi a Kau describe using 'Orongo, Rano Raraku or "big" *ahu* sites for birdman cult related initiation ceremonies (*poki manu*) during times of social difficulty (Routledge 1919:267).

An increasingly persuasive body of ecological and archaeological data reveals that the Rapa Nui natural and social environment was under generalized and probably intensifying stress, although the extent and ramifications of that stress are not fully known (Flenley 1979; Flenley et al. 1991). A single, oft-repeated but archaeologically reputed Rapa Nui legend (that of the Poike "ditch" confrontation between the "Long Ears" and "Short Ears" in AD 1600s) has long been the basis of a supposedly fatal, island wide conflagration which resulted in the complete downfall of Rapa Nui society. This myth, coupled with overgeneralized ecological data, has been partly responsible for the gross oversimplification in the popular press of Rapa Nui history as a global "metaphor for disaster" (cf. Bahn and Flenley 1993). It is inconceivable to me that the Ahu Akivi megalithic accomplishments could be even roughly contemporaneous with such mythic and vastly destructive warfare as that implied by the literal interpretation of myth and legend. In short, this research strongly recommends that a distinction be made between the island environment as it is increasingly understood and the projection of Western value judgments on the poorly understood behavior of Rapa Nui people in response to that environment. A reassessment of many previously unexamined and largely facile assumptions about late pre-contact Rapa Nui culture is long overdue.

While sufficient agricultural crop foods, water and the minor wood resources required for the hypothesized transport task are presumed to have been available to the Ahu Akivi *ariki*, other non-Miru political units probably did not always have sufficient access to protein and fat previously supplied to their diets by marine and bird resources now depleted (Steadman et al. 1994). The availability of foods of all types

(famine, subsistence and feast) was dependent upon a myriad of as yet not fully understood socio-political and environmental variables. While the *tangata manu* cult may be interpreted as an ideological adaptation to food resource availability (cf. McCoy 1978), it was also a response to the vagaries of unequal resource access and the evolution of the political system.

Conclusion

The transport model presented here is not a shot in the dark. It has utility because it employs a statistically average *moai* and allows for replication and generalization. It was built upon known ethnographic evidence and successful experimental archaeology in many cultures, and developed through the application of tests of reason, simplicity, resource availability, terrain configuration, cultural pattern and archaeological context. This research has many applications and potential uses. Optimal path studies may be expanded through the employment of alternative criteria and constraints, and lend themselves well to further experimentation.

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End Notes

¹The significance of maritime symbology (fishhooks; canoes in the form of the crescent and modified crescent) is evident

in Rapa Nui art and domestic and semantic architecture of several types (Van Tilburg and Lee 1987; Van Tilburg 1994). At the time Ahu Tahai and environs (including, apparently, the "canoe ramp") were constructed, sufficient palm wood resources probably existed in the near vicinity of Tere Vaka to construct modest rafts or sledges for either overland or water transport of anything, including statues (all of which are between 235 and 501 cm tall). Seagoing rafts (all of which require more wood than the sledge we designed) are best described for the Tuamotus and Mangareva, where they could accomodate approximately twenty people (cf. Buck 1971:281-83).

The Mangarevan-like custom of a ranking chief sitting, standing or being carried on a wooden platform was reported for postcontact Rapa Nui by Routledge's informant Te Haha (who also said that sometimes the *ariki* and his son sat on "seats" made of *kohau rongorongo* during ceremonies at Anakena; Routledge 1919:245). This, and the treatment of some portable god figures on other islands, might suggest that some *moai*, under unknown ceremonial circumstances, might have been similarly carried, although it is purely conjecture. The island's geography, however, is a persuasive argument in favor of overland statue transport as regularly chosen methodology (as for stone in the Marquesas Islands; Linton 1925:10). Unlike other megalithic sites in Micronesia or Tonga, for example, where reef enclosed, calm waters were easily employed for transport tasks, the Rapa Nui shoreline is notoriously dangerous to watercraft of all kind.

²The maximum force required to pull the average statue in a horizontal position on the sledge we designed is two and one-half tons. In an upright position the same statue requires two and one-third tons of force to tilt. Balanced by the danger of falling, the scant energy saved is of little consequence. Pulling the upright statue on a "pod" of logs over rollers uses nearly the same amount of wood as does a sledge, so resource economy is negligible. Manpower needs, however, are about half. The most obvious argument against upright transport is the Rapa Nui terrain. An upright statue, either tilted and swiveled on its base or supported by a "pod" of logs, falls often on a ten degree slope and nearly all of the time on a 20 degree slope. Nearly all of the "in transport" statues are larger than average, a fact which makes upright transport even more dangerous. Finally, our cumulative research clearly suggests preliminary support for Routledge's (1919) earlier notion that many of the "in transport" statues were, in fact, standing in place.

³The Fijian double canoe (*wangga ndrua*) was the largest and finest precontact Polynesian vessel known at contact. As in Hawai'i and the Society Islands, hulls were hewn inland, in the great hardwood forests, and then transported overland where the canoe was completed before being launched over rollers into the sea. One hull, called "Perished inland," was 118 feet long and too large to move. Most hulls weighed from 6 to 12 tons. When one reads the accounts of commissioning and carving these vessels, one need only substitute the word "statue" for "canoe" to have a reasonable picture of how the average megalithic task was accomplished on Rapa Nui, socially and practically (cf. Haddon and Hornell 1975:328-9).